pared chemical products. What a boon if we could replace the lacking products, not by repeated introduction from without, but by constant steady elaboration from within the body itself! What a triumph if we could give back to the myxedematous patient a working thyroid, to the diabetic a functioning insulin apparatus, and to all the other sufferers from endocrine insufficiencies the living tissues that would restore them to normal health and function! Surely this is a dream worth cherishing, and an attainment worth working for.

SUMMARY OF PRESENT CONCLUSIONS

But while we naturally and rightly cherish our dreams of future possibilities, we emphasize again that we are not deluded and wish to delude no one else as to the limited extent of our actual present results. It may be well to conclude this paper with a brief summary of our conclusions, and their meagerness will act as a correction to any overenthusiasm that may be inferred from the preceding paragraph.

1. The success of grafts of endocrine glands depends on at least three principal factors, and possibly others not yet known. Those factors are the site at which the graft is placed, the physical form of the grafted tissue, and the chemical adjustment of the graft to the host.

2. As concerns the site of the graft, it should be placed in a location of loose structure, free from pressure, near a good blood supply but not too vascular, and easy of access.

3. As concerns the physical form of the graft, it should be either in finely divided fragments of the original gland, or in the form of tissue cultures grown from the original gland. Such forms of graft permit the individual cells to come in close and quick contact with nutrient substances without depending at first upon the development of an organized blood supply.

4. The chemical adaptation of graft to host may be sought by growing the graft as a tissue culture in a medium made up from fluids of the host's body, thus providing an opportunity for preliminary adjustment of the graft to its future chemical environment.

5. By the observance of these requirements, in a series of experiments thus far not sufficient to be conclusive, a promising measure of success has been attained.

6. The subject as a whole is full of such great possibilities of clinical value and scientific interest that it deserves active and earnest prosecution.

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THE KNEE JOINT—ITS FUNCTIONAL ANATOMY AND THE MECHANISM OF CERTAIN INJURIES*

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Any consideration of the functional anatomy of the knee joint and of the mechanism of injury, historically, focuses attention on the work of four men. One hundred and fifty years ago William Hey [1] of Leeds recognized clinically and treated successfully the condition known as internal derangement of the knee joint, and was the first medical man to invade this province of the bone setter. To Edinburgh we turn for the work of the other three. There, John Goodsir,[2] the master anatomist, carried out his remarkable work on the mechanism of the knee joint while professor of anatomy during the years 1846-67. To his demonstrator, Thomas Annandale, who succeeded Lister as professor of surgery in Edinburgh, fell the distinction of performing the first operation for a tear of the semilunar cartilage. This operation was performed in 1883, just fifty years ago, and was followed by the experimental work of Annandale's pupil, Scott Lang,[3] who carried out the earliest experiments on the mechanism of production of such internal derangements of the knee joint.

This paper is very largely an expression of personal opinion derived from repeated examinations of the knee joint, in health, in injury, and on the cadaver.

From time to time I have repeated much of the work of others and so I am very largely in agreement with their interpretations except in certain details. It is not possible in such a short discourse to enter into a critical examination of the literature, nevertheless wherever I have cited others I have personally verified and agree with their opinions.

THE KNEE JOINT STRUCTURE AND MOVEMENTS

The knee joint is a double articulation enclosed in a common synovial membrane. Of these two articulations the chief is that which occurs between the femur and the tibia, which also is in itself double. The articulation between patella and femur will not be discussed in this discourse; and in what follows, knee joint refers arbitrarily to the tibiofemoral joint.

The knee joint, classed as a freely movable or diarthrodial joint, conforms to a general principle which is characteristic of most, if not all, such diarthrodial joints. This principle is exhibited in a dual function of the articular surfaces. Diarthrodial joints, and especially those of the lower extremity, must subserve two purposes. As Walmsley,[4] following Goodsir,[2] puts it, the first is the transmission of body weight through a temporarily stabilized couple, the components of which are displaceable; and the second is the free movement of the components on one another by the action of the related muscles. Stabilization of a joint is

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brought about when the joint surfaces are largely in contact with one another and fully congruent, the joint being converted in a functional sense from a diarthrosis to a synarthrosis (Walmsley [4]). It is this congruity of surfaces which occurs in joints when they are said to be screwed home or locked in the position for weight transmission. The articular surfaces of the knee joint become most fully congruent in complete extension, which is the position of "stable equilibrium" for that joint. We find, therefore, that anything which interferes with this full congruence leads to one of the causes of instability described by the patient subjectively as a "weakness" in the joint.

In the next phase, the phase of movement, the articulating surfaces are incongruous, a functional relationship of the greatest importance, as Goodsir [2] showed. By this means, joint surfaces when in motion are part in action and part at rest, which allows of reparation and nutrition. This mechanism is evident in the knee joint and is enhanced by the action of the menisci, as will be discussed below.

The movements of the knee joint are primarily those of flexion and extension, but an important rotatory movement occurs in conjunction. These movements are related to the shape of the articular surfaces and are controlled by and associated with the ligaments, menisci and muscles. The femoral condyles in passing from flexion to extension do not roll upon the condyles of the tibia; if they did, the femur would have a progressive forward movement which would eventually end by the femur rolling completely off the tibia. Therefore, with the tibia fixed, as in walking, the femoral condyles in extension must slip or "skid" progressively backward, as does the locked wheel of a vehicle skidding on a slippery surface, with a continued forward momentum.

The effect of this backward skidding of the femoral condyles, which of course is only relative, is to alter the relationship of the fixed points of attachment of the collateral ligaments. Taking the tibia as fixed, the superior attachments of these ligaments are carried further backward and upward; that is, the distance between these fixed points of attachment is increased, so that these ligaments become progressively more taut, a part of the mechanism to stabilize the knee joint in extension. The rotation which completes extension enhances this effect. As the medial meniscus is attached to the tibial collateral ligament, tightening of this ligament in extension serves partly to draw the meniscus out of the pathway of the oncoming condyle. This mechanism is important in internal derangements. The tibial collateral ligament is invariably damaged, whether alone or with other ligaments, when undue lateral mobility or rotation occurs with the joint in full extension—a relationship which will be considered in the discussion on the cruciate ligaments.

The long axis of the tibial surface of the medial femoral condyle is set at an angle of some 15 degrees to the anteroposterior vertical plane. This surface forms part of an arc of a circle whose center is lateral to the knee joint and whose radius is about six inches in length; so that, with the tibia fixed, when extension occurs this movement becomes complicated by one of medial rotation of the femur on the tibia, the articular surfaces following their axes. This movement of medial rotation commences early, but becomes progressively more evident as full extension is approached. As the center of this rotatory movement lies lateral to the lateral femoral condyle, this condyle, being within the circle of this movement, has to "mark time" for the medial femoral condyle. Therefore the lateral meniscus is more nearly a circle to provide for this pivotal action. The medial rotation of the femur on the tibia in full extension renders the articular surfaces and menisci fully congruent with one another, and the knee is in a position of stability for weight transmission and is said to be screwed home or locked. Full extension at the hip likewise screws home that joint in full congruence, so that in the erect posture a stable column for weight transmission is formed from trunk to ground (Walmsley [4]). The limb, with joints in stable equilibrium, supported by tightened ligaments, assisted by muscle tonus and gravity, forms a rigid but resilient column for the support of the superincumbent weight, with a minimum of muscular effort. Release of this lock in walking is effected by tilting forward of the body at the pelvis to undo the hip joint and by the action of the popliteus muscle in producing lateral rotation of the femur at the knee. The popliteus muscle can, therefore, be looked upon as the "priming" which sets the knee joint in motion.

FUNCTION OF THE MENISCI

It is usually said that the function of the menisci is to compensate for the incongruity and, by movement, to pack the opposed femoral and tibial surfaces. That this is not the case is evident to anyone who has examined these cartilages during movement. As already mentioned, they are fully congruous in only one position of the joint, namely, in full extension when the joint is stabilized for weight transmission. In movement, they tend to increase the disparity between the surfaces and set themselves to form cuneiform spaces between the moving parts. MacConaill [5] has recently given a new and most satisfactory interpretation of the function of such articular disks as found in joints. By reference to the theory of lubrication, he has shown that intra-articular cartilages relate primarily to the synovial fluid, rather than to the articular surfaces of the bones. The menisci, by the production of such cuneiform spaces, create a positive pressure of synovial fluid between the opposed surfaces and so prevent their premature approximation. In this manner they play an active rather than a passive part. MacConaill [5] makes an interesting comparison between the menisci of the knee joint and the so-called Mitchell thrust pads. The Mitchell thrust pads are a refinement of marine engineering and are employed when thrusts are to be carried by a film of lubricant during motions in which there is a considerable element of gliding, and in which a screw-like movement along the axis of thrust is discouraged. Such pads or menisci increase the efficiency of joints in the higher ranges of motion and, therefore, surgical removal of a portion of a meniscus does not, under ordinary circumstances, lead to symptoms. In fact, there is often an incomplete fibrous replacement of the cartilage after removal which tends to restore the normal condition, and which may in turn be injured, giving rise to diagnostic difficulty. In many cases removal leads to the development of osteoarthritic changes from increased friction. Furthermore, the argument that these intra-articular disks are but vestigial remnants is not borne out by the facts of comparative anatomy which, on the contrary, shows them to be new mammalian acquisitions.

Experimentally, it is not difficult to see how lesions of the menisci are produced, and there are several maneuvers which will cause such lesions. In flexion, the lateral cartilage moves backward as a whole and becomes more nearly circular. The anterior horn of the medial cartilage is drawn toward the center of the joint, and as this cartilage is fixed at about the center of its periphery to the deep aspect of the tibial collateral ligament, it is drawn exceedingly taut. Forcible lateral rotation of the leg increases this effect and may lead either to bodily displacement of the cartilage, or to tear of the cartilage at the junction of its mobile and fixed portions or to a tear of the "bucket-handle" type. As to whether the "bucket-handle" type results or not seems to depend upon the nature of the attachment of the anterior horn, which varies somewhat in different specimens. In this connection it may be of interest to record that the torn medial cartilage has been seen drawn across to the extreme lateral side of the joint, causing a confusion in diagnosis. On the other hand, sudden extension, combined with rotation, may tear the cartilage longitudinally and increase the damage to an already displaced or torn meniscus. Forcible medial rotation of the leg tends to damage the lateral cartilage, although this effect is variable. It is much more difficult to elucidate the mechanism of injury to the posterior parts of the cartilages. While I have not been able to produce such lesions on the cadaver, yet I have noted that the greatest stress would seem to be thrown on the posterior parts of these cartilages when the limb is forcibly rotated and then suddenly flexed to its maximum. Damage to the lateral cartilage is said to give rise to the "clicking" knee, and it is possible, with slight damage to the articular surface, to reproduce experimentally such clicks when the lateral cartilage is displaced.

THE CRUCIATE LIGAMENTS

The cruciate ligaments lie obliquely between the condyles of the femur and it is important to remember that they exist in part in the anteroposterior plane and in part in the mediolateral plane. Their disposition in the anteroposterior plane and their eccentric attachment account for the orthodox view that the anterior ligament tightens and limits extension, the posterior, flexion. Actually, however, both are taut in extension, because extension is complicated by rotation and because of the more extensive attachment of the posterior cruciate ligament. The disposition of these ligaments in the mediolateral plane is of great importance in guiding and controlling rotation of the leg, an effect supplemented by the oblique position of the oblique popliteal ligament. For this reason rupture of the anterior cruciate ligament, often associated with injury to the medial meniscus, is not attended later by loss of stability in the joint.

I have recently examined four cases in which there existed a rupture of the anterior cruciate ligament proved at operation. None of these exhibited any disability whatsoever, and in none was there any instability or increase in motion in any direction except for a slight increase in lateral rotation of the leg when the limb was flexed.

Pringle,[6] experimenting on the cadaver, reports similar results. This may be due to the fact that the oblique popliteal ligament is supplementary to the anterior crucial. Excessive mobility and instability occur only when this injury is accompanied by a rupture of the tibial collateral ligament. Pringle states that in those instances in which he succeeded in rupturing the anterior cruciate ligament on the cadaver he found, on examining the ligaments of the joint, that there was always a degree of tearing of the tibial collateral ligament at its deep or articular aspect, and that this tearing was incomplete, never involving the superficial fibers. This raises the question of the desirability of carrying out extensive and difficult reconstruction operations within the joint. I am not in favor of these, nor are they indicated except in cases of gross injury. Repair and reconstruction of the collateral ligaments seems, from my experience, to be the logical procedure, since in those cases that exhibit instability the lesion of importance is a tearing of the tibial collateral ligament and often of fibers which are deep and, therefore, not evident.

The posterior cruciate ligament is shorter, has much more extensive attachments and, therefore, its rupture is much rarer. This injury is more serious, is often complicated by extensive damage to other structures, and clinically permits of abnormal backward displacement of the tibia. It seems to be produced when the tibia is forcibly driven backward with knee in full flexion (Pagenstecher[7]). The ligament is safeguarded from rupture in full flexion by contact of calf with thigh.

The foregoing discourse is but a summary of the more salient features in the mechanism of the knee. Study, by experiment and dissection, is the only way to gain real appreciation of the action of this remarkable joint.

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